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Cereal Virus Diseases in Britain . . *Marion A. Watson* 93

Measurement of Performance in Machine Milking
P. A. Clough and F. H. Dodd 103

Scientific Principles of Livestock Feeding: Part I
S. M. Boden 111

Estimated Quantities of Lime needed in the United Kingdom on Agricultural Land . . . . . *E. Roberts* 120

The Work of the Analyst . . . . *A. J. Cavell* 122

Farm Management Notes . . . . . *K. Dexter* 128

REGIONAL NOTE

Commercial Practice in Rose-growing Nurseries in the East Midlands Region . *A. W. Smith and L. W. Wallis* 132

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Cereal Virus Diseases in Britain

MARION A. WATSON

Rothamsted Experimental Station, Harpenden

FOUR VIRUS DISEASES of cereals and grasses have been described or identified in Great Britain during the last four years: cereal yellow dwarf, European wheat striate mosaic, rye grass mosaic and barley false stripe. They are transmitted respectively by aphids, delphacid leafhoppers, mites, and seed and pollen.

Cereal Yellow Dwarf Virus

At present the most important economically is cereal yellow dwarf virus. This was first described by Oswald and Houston in 1953 [4]. Attention was drawn to it by the apparently sudden appearance in "most barley-producing countries" of an injurious disease of barley, whose principal symptoms were dwarfing of the plants and yellowing of the tips of the leaves. As with many viruses of field crops the serious outbreak of disease led to the identification of the virus. Once Oswald had isolated it, he realized that it had occurred sporadically in cereal crops for many years, but the symptoms had not been distinguishable from the many other causes of yellowing in cereals.

The first cereal virus isolated in Great Britain came from a few yellowed plants in the headland of Long Hoos barley experiment at Rothamsted. They were selected because they seemed to resemble Oswald's description. They showed yellowing of the flag leaf and delay in emergence of the ear within it, in contrast to conditions such as nitrogen deficiency, or root fungus diseases which usually cause yellowing from the lower leaves upwards. However, this symptom is not always diagnostic, for it may occur with other nutrient deficiencies, e.g., the writer has seen it in potash deficient barley plots. The symptoms of yellow dwarf are more easily diagnosed in oats, because of the bright red or purplish discoloration, but there is still uncertainty, especially as virus is not always transmitted in glasshouse tests from field plants apparently showing characteristic symptoms of infection.

THE FIRST SERIOUS OUTBREAKS

For a time, the study of yellow dwarf seemed to be a subject of purely academic interest, because for several years the only plants found were isolated specimens. Then came the mild winter of 1956 followed in 1957 by the earliest and largest spring migration of aphids ever recorded. Symptoms appeared much more plentifully in the spring crop. With the help of the advisory services, specimens were obtained from many parts of Great Britain, and a considerable number contained the virus. At least two specimens, one from North Wales and one from Kent

yielded much more virulent virus (YDV), than that collected at Rothamsted, and it was obvious that the disease was a potential menace to any crop that became infected in a young stage of growth.

There was not long to wait, for many winter crops, particularly oats in the south of England became severely infected during the winter of 1957-58, with very serious effects on yields.

Investigation of this disease has been curiously like that of beet yellows virus, which also was first isolated from a few yellowed plants on Rothamsted farm, where it appeared to be doing little harm to the crop. Observations made in the southern and eastern counties in 1940-42 gave no indication that beet yellows would ever become sufficiently widespread to cause serious damage [11]. At this time most of the virus isolated from the field was avirulent, but virus causing more virulent symptoms was isolated and replaced the mild virus in experimental work. The potential menace to the crop was then recognized, but it was not until 1943 that a serious outbreak actually occurred in the seed-crop growing areas of Lincolnshire. In 1944 and 1945 outbreaks increased in size and severity, and from that time only the virulent necrotic types of beet yellows virus could be isolated from the field; mild types were sought, but not found. In 1950 measures were taken to break the cycle of overwintering virus and spring infection of the root crop, by controlling the spread of virus in the seed crops. After this there were several years of reduced incidence of beet yellows, and in 1957 avirulent viruses again appeared in the field. Fifty-two out of 140 specimens collected in East Anglia contained them [6]. The same sequence may be occurring with cereal yellow dwarf viruses.

EFFECTS OF YELLOW DWARF ON WHEAT, OATS AND BARLEY YIELDS

Since 1955 small-scale field experiments have been made in which plots were infested with virus-carrying *Rhopalosiphum padi* [13] under muslin cages, and the yields compared with those of untreated plots or those fed on by virus-free aphids. The results for the first three years are summarized in Table 1.

Losses were very variable and sometimes negligible. This was partly a result of using the avirulent virus (YDA), and partly because it was not possible to infect each crop at the same stage of growth in each year. The results suggested that most of the crops and varieties tested could lose up to 30 per cent of their potential yield if infected at the right time, but we were not able to distinguish the critical times. The 1958 experiment compared both YDA and the virulent virus isolate, YDV, on infected and healthy crops of wheat, oats and barley (see Fig. 1 on p. 96).

Koga II wheat and Proctor barley infected with YDV at the earliest date lost two-thirds of their potential yield; Blenda oats lost four-fifths and probably would have produced no grain at all except that a few plants escaped infection. A few plants also remained healthy for a time

Table 1

Losses of Yield caused by Avirulent Cereal Yellow Dwarf Virus (YDA) in Varieties of Wheat, Oats and Barley, tested 1955-1957.

		25-30 April *per cent*	3-4 May *per cent*	12-14 May *per cent*	
BARLEY					
1955	Plumage Archer	37	19	—	± 5.5
1956	Maythorp	24	—	20	± 11.2
	Rika	20	—	2	
	Provost	42	—	21	
	Proctor	26	—	8	
1957	Herta	0	−6	−7	± 3.9
	Proctor	16	−2	15	
WHEAT					
1956	Atle	3	—	33	± 11.2
	Bersee	14	—	34	
	Koga II	20	—	20	
	Rescue	11	—	16	
1957	Atle	−6	0	−5	± 4.9
	Koga II	−4	6	−9	
OATS					
1956	Milford	23	—	35	± 11.2
	Onward	5	—	12	
	Blenda	32	—	33	
	Stormont Iris	−4	—	19	
1957	Milford	17	17	16	± 7.1
	Blenda	37	27	22	

in the wheat and barley plots. YDA virus caused smaller losses, roughly comparable with those caused by YDV. There are several divergencies from expected trends in the data that may be of interest, but the full results and statistical analysis are not yet available.

GLASSHOUSE EXPERIMENTS WITH YELLOW DWARF VIRUS

Like beet yellows virus, the yellow dwarf viruses are persistent. The vectors probably remain infective for at least a week or ten days after a single adequate feed on infected plants. The most successful vector of both yellow dwarf viruses is *Rhopalosiphum padi*, which can infect 60 per cent of the plants fed on by single individual aphids carrying YDA, and 80 per cent if they are carrying YDV. *Sitobium fragariae*, *S. avenae* and *Metapolophium dirhodum* transmit both with varying degrees of success. We have no evidence that either virus is specifically transmitted by different aphid species, as has been described for comparable isolates by Toko and Bruehl [10] in America.

Sixty-two species of Gramineae belonging to 14 genera have been tested for susceptibility to yellow dwarf in Great Britain and America. On the whole there is agreement between the two estimates of host range. All the cereals including maize and rice are susceptible, so are many species of Agrostidae, Hordeae, Phalaridae and Festucaea. The only species we have found to be almost certainly immune are *Agropyron*

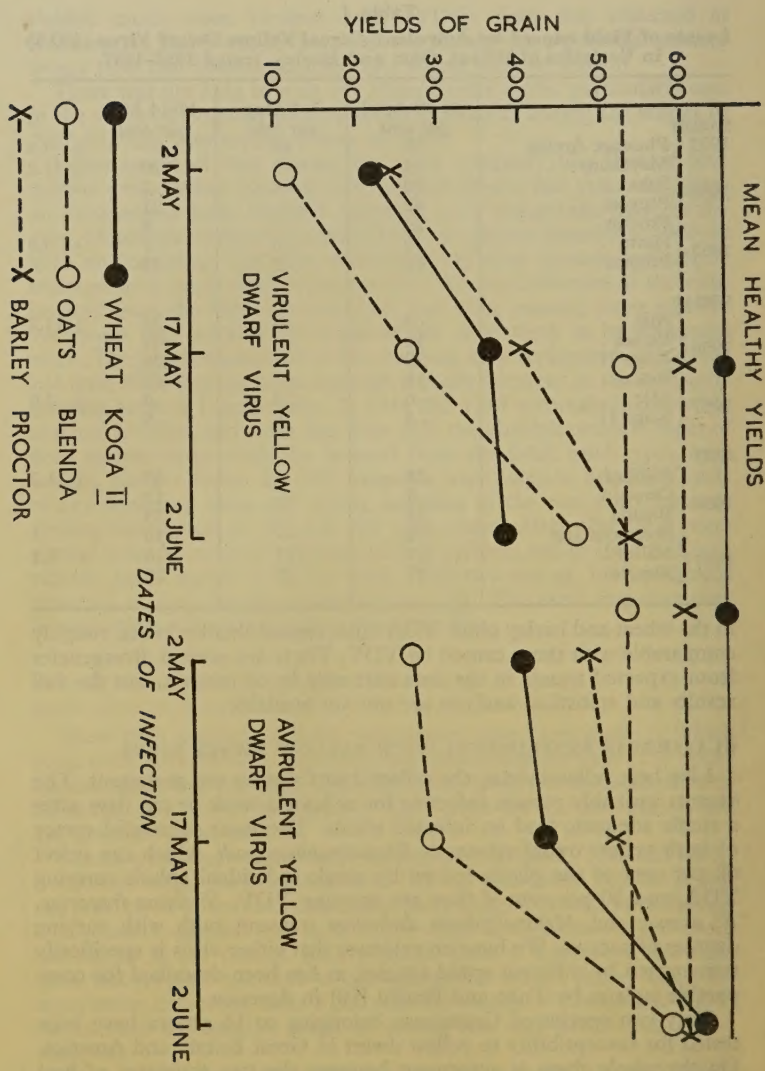

FIG. 1. Yields of wheat, oats and barley infected at different ages with avirulent and virulent strains of cereal yellow dwarf virus. Mean yields of uninfected plots are given as horizontal lines at the appropriate levels.

repens (Pers)., *Arrhenatherum elatius* (L.), and *Agrostis tenuis* (Sibth.). Even with YDV some of these species seem to be symptomless carriers; others show no symptoms other than a slight reduction in size. Many are dwarfed and show typical yellowing, or red discoloration of the leaves. Plate I shows two species of *Bromus*, perennial ryegrass, and Blenda oat all infected at the same time with YDV. The infected ryegrass is slightly "poorer"; the oat and *Bromus arvensis* are dwarfed, and *B. sterilis* shows very marked discoloration of the leaves, which is purplish red in the original.

Not many attempts have been made to recover the virus from naturally infected grasses, but often their appearance in nature is strikingly like that of plants infected experimentally. The red leaves of *B. sterilis* are so common that they seem a permanent characteristic of the species, but in the glasshouse, healthy *B. sterilis* remains green and only the infected ones turn red. We do not know the extent to which wild and cultivated grasses act as reservoirs for the virus or what part they play in transferring it to the cereal crops.

CROSS-INOCULATION EXPERIMENTS

No anti-serum has yet been obtained for YD viruses so we could not use this method for determining their relationship with each other. However, the symptoms of YDA and YDV are sufficiently different for cross-inoculation experiments to be carried out, and, as with the yellowing viruses of sugar beet, [12], these experiments gave evidence that the two are not strains of the same virus but different viruses with similar properties. Plants showing symptoms of YDA, when inoculated with YDV, became just as dwarfed as healthy plants of the same age inoculated at the same time, and virus recovered from these plants produced typical YDV symptoms when re-inoculated into healthy seedlings.

Both yellow dwarf and sugar beet yellows viruses cause accumulation of carbohydrate in the discoloured portions of infected leaves. Cereal leaves do not usually form starch, but starch and reducing sugars are found plentifully in YD infected wheat and oats. Sometimes this sugar concentration is strong enough to be detected by taste, and it seems possible that some laboratory test for the presence of virus might conceivably be based on it. This would be extremely useful, for the disease is not easy to diagnose by eye observation, and even aphid transmission tests in the glasshouse are not always successful. Whether it is that other conditions simulate virus, or that there are strains that are not transmissible by our test insects, or that plants infected for a long time in the field contain little virus, it is impossible to say.

Wheat Striate Mosaic

Wheat striate mosaic is transmitted by a fulgorid leaf-hopper, *Delphacodes pellucida* (Fabricius). Like yellow dwarf it is persistent and non-sap-transmissible. The symptoms, shown in Plate III, centre, start

with fine discontinuous streaks along the veins of affected leaves, rather like "tacking stitches" of fine thread. These broaden and coalesce until almost the whole leaf is yellowed, and dies. If infected within the first two months of growth all the leaves become yellowed and most plants are killed by the virus [9].

The photograph in Plate II, right, is of plants taken from the Rothamsted farm on 22nd May, 1958, when about 0.02 per cent of the plants were infected. A month later scarcely any infected plants could be found. Apparently, none had become infected at any later stage than those we had already seen, and those plants had died, or become smothered by their healthy neighbours. So there appeared to be less infection than at the previous time, and no evidence of spread from plants that were then showing symptoms. This suggested that the vectors had entered the crop carrying the virus but had not bred or multiplied on the wheat plants. The instance was not an isolated one. When the virus has been found in wheat, whether early or late infected, there has been no evidence of spread from the plants first observed. The virus has infected all the varieties of wheat, oats, barley, rye and ryegrass we have tested, and could undoubtedly cause serious losses to crops if it spread rapidly in the field. In 1957, Dr. Mary Glynne brought specimens from Spain that were found to be infected with WSM virus. Patches of similar plants were common in the crops that she observed, so spread of the virus does not seem so restricted there as here. It already occurs frequently in this country, although it infects few plants in any crop, and similar diseases have been recorded from other parts of Europe and from Russia [8].

WHY DOES THE VIRUS OFTEN INFECT ONLY A FEW PLANTS?

To find out how the virus so frequently enters the wheat crops and infects a few plants without spreading within the crop, we must consider its properties, and in particular, its relations with its insect vector. Like the aphid-transmitted viruses already mentioned, WSM virus is persistent and non-sap-transmissible. It resembles other leaf-hopper transmitted viruses in undergoing a long "incubation period" within the body of the vector between the time when the virus is acquired during feeding on infected plants, and the time when the insect becomes able to transmit. This interval can vary from about 7 to 30 days, and seems to be largely independent of the length of time that the vector has fed on infected plants, although it cannot be measured at all if they feed for too long.

D. pellucida exists in a number of races that vary in their ability to acquire and transmit virus; i.e., in the proportion of individuals belonging to a particular group or race that are able to infect in comparable conditions. We have three races of *D. pellucida* which regularly transmit to 90-100 per cent, 40-50 per cent and 10-20 per cent respectively of the plants tested, and we refer to them as highly efficient, efficient and inefficient races [14]. We have no information about the proportions

of these different races that exist in field populations, but there is indirect evidence that the least efficient may be in the majority.

American workers have long maintained that the incubation period is a period of multiplication of a virus within its insect host. There seems little doubt that this is true of wheat striate mosaic in *D. pellucida*, for the efficient races of hoppers transmit the virus to a high proportion of their progeny. The virus enters the eggs of infective mothers, and if the mothers belong to a highly efficient vector race, the nymphs can start to transmit almost as soon as they are hatched. The virus is not transmitted by an infective male to the progeny of a virus-free female, but is inherited through the female parent only. Vector-efficiency can, however, be inherited through either parent. Egg transmission of the virus is proportional to vector efficiency. It is common among females of highly efficient races, and a large proportion of their nymphs, up to 100 per cent, may be infective. Egg transmission is very rare among inefficient races, even if the mothers are infective; indeed only one instance of egg transmission in a very inefficient race has been recorded.

EFFECTS OF CLIMATE

Both the multiplication of the virus in the vector and its inheritance through the egg are important to the dissemination and survival of the virus, and therefore of great economic importance. Hoppers are on the whole heat-loving insects. They flourish in warm dry climates, hence the spread of curly top virus of sugar beet in California, but in England they do not usually become very numerous on any particular crop except in occasional spells of warm summer weather. It is extremely doubtful whether *D. pellucida* could survive even a mild winter in the adult stage, but it probably does in the form of eggs laid in the leaf sheaths of hedgerow and meadow grasses. It is doubtful whether they would start to breed early enough in spring for wheat to become infected at the end of May, if the virus had to depend on being picked up by the first generation of hoppers feeding on meadow grasses. It is even uncertain how many of these grasses are susceptible to the virus; we are only sure of *Lolium* spp. However, a number of these eggs give rise to nymphs that are already infective, and whether or not they feed on infected grasses until they are adult, they will carry the virus with them when they migrate into the wheat crop. If they multiplied on the wheat the virus would spread, but it does not do so. Probably they feed in spring only in sheltered places. When they move on to the young wheat there is little shelter, so they usually do not survive, although they might do so in a particularly fine and warm May and June. Presumably they do survive in Spain, which is why the virus appears in large patches there and only on isolated plants here.

Ryegrass Mosaic

The writer is indebted to Mr. T. Mulligan for the substance of the following notes on ryegrass mosaic which was isolated by Dr. Slykhuis

from cultivated grasses in Hertfordshire in 1956. It was found to be sap-transmissible, but not transmissible by aphids or by leaf-hoppers. As the virus in some ways resembled wheat streak mosaic [7], a collection of mites was made, several of which were found to belong to the Eryophyid group. These successfully transmitted the virus to a small proportion of ryegrass seedlings, and eventually the vector was identified, by a process of elimination, as *Abacarus hystrix* (Keifer). This is a small elongated translucent mite, about 0.2 mm long, that lives in the grooves on the surfaces of grass leaves. Its eggs hatch into active nymphs resembling the parents. The life history probably takes about three weeks. Several species of these mites appear identical, even under the microscope, and distinctions between them depend on minute characteristics, so it is not easy to obtain a pure culture, or to replace them if it fails.

The mites have not much mobility, and the virus is probably spread by wind dispersal of infective vectors [7], though infested leaf fragments could also be carried by machinery or grazing animals.

Some of the properties of the virus have been determined by sap inoculation. It is fairly stable at room temperature and serologically active. It has a wide host range among the Gramineae, but no dicotyledonous hosts. The host range is difficult to determine precisely, because in several genera of grasses some species are susceptible and others are not. In some species varieties respond similarly, and a species described as immune, may later be found to have susceptible varieties.

SUSCEPTIBLE PLANTS

Of the cereals, oats (Plate II, left), and rice are susceptible but not wheat, barley or maize. The virus was isolated from some naturally infected oat plants sent by Mr. E. Lester from Berkshire. They had been collected in the field because of their severe necrotic symptoms. It is common in old meadows or grass leys, particularly of Italian or perennial ryegrass (Plate III, left), which are the most favourable hosts for the virus. *Festuca pratensis*, *Cynosurus cristatus* (L.), *Poa annua* and *Dactylis glomerata* (L.) are important susceptible grasses.

Ryegrass plants inoculated as seedlings in pots in the glasshouse lost 30-40 per cent of their yield compared with healthy plants, and plants infected in the glasshouse and grown outside sometimes form rather poor tussocks, but vary in their appearance. So there is little information about possible damage that the virus might cause to hay crops or grass leys.

Probably the reason for varietal differences in response to infection is that there has already been selection for resistance, susceptible plants in breeding material having been eliminated because of their poor appearance when infected.

Barley Stripe Mosaic Virus

Barley stripe mosaic virus [3], has only once been isolated from a crop

in Great Britain. This was Gloire du Velay barley grown from seed imported from France. Its presence was suspected in a variety "Olli" imported from Canada, but could not be confirmed.

The symptoms (Plate III, right), vary on different varieties of barley from a mild chlorotic mottle to a severe necrotic streak that rather resembles the "stripe" caused by *Helminthosporium sativum;* for this reason it was at first called barley false stripe. The characteristic symptom in very susceptible hosts is a chlorotic streak bordered by a narrow region of bronze necrosis, which eventually spreads and kills the leaf.

Kassanis and Slykhuis [1], from whom most of this information is obtained, tested twenty varieties of barley. The least tolerant were some barley selections from the Plant Breeding Institute at Cambridge, H.B. 117/23 2, and H.B. 169/5 22/6. These became 100 per cent infected, with severe necrotic symptoms. The most tolerant were Rika, Spratt Archer, Plumage Archer and Maythorp, which gave mild symptoms on only about 10 per cent of the plants inoculated. Of other varieties commonly grown in England, Proctor was moderately tolerant and Provost moderately susceptible. Some wheat varieties and Italian ryegrass were also found to be susceptible.

BSM virus is the only one of the four cereal viruses here described that has dicotyledonous hosts. Kassanis and Slykhuis found that sugar beet and *Chenopodium amaranthicolor* developed chlorotic lesions on inoculated leaves, but did not become systemically infected; summer spinach (*Spinaceae oleracea*) developed systemic symptoms of a bright yellow mottle in the form of rings, or "oak-leaf" patterns.

The virus was found to be rather stable in extracted sap, infective to a dilution of around 1/2000, and serologically active. Rod-shaped particles were observed in electron micrographs, and were much more numerous than the infectivity and serological dilution end points would suggest. BSM virus is transmitted through the seed of infected barley plants, and with susceptible varieties a high proportion of the progeny are infected. It also possesses the unusual property of being transmitted through the pollen, and virus particles have been seen in electron microscope preparations made from pollen grains collected from infected plants [2].

The virus does not seem to be a problem at present for cereal growers, but it is something to be watched for, particularly in cereals grown from imported seed. According to American and Canadian workers the disease can cause very serious losses in barley and other cereals. It is potentially dangerous in breeding stocks in this country, but plant breeders are now on their guard against it, and will be taking all possible precautions.

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Measurement of Performance in Machine Milking

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ADVICE given to farmers on the rationing of dairy cattle is based on generally accepted standards of feeding. These standards are not absolute, but their use gives satisfactory results. This situation contrasts with the advice generally given on systems of machine milking. Here there are few generally accepted standards and the advice given is not unnaturally coloured by whether the adviser is mainly concerned with animal husbandry, engineering, dairy hygiene, labour economy or veterinary medicine. The object of this article is to examine briefly the principles that govern the performance (i.e., number of cows milked per man-hour) in a milking installation, and to put forward a scheme that can be used to calculate the correct unit size of installation required for a herd or the efficiency of an existing installation. The scheme is a development of, and should be read in conjunction with, the principles outlined in a recent article [1]. In this, milking parlours were classified into the two basic types, having one or two stalls with each unit. The differences between the work routines of these basic types were discussed and also the time requirements for the various operations required for each cow that is milked. These work routines are based on work study measurements made in well-organized milking parlours.

Factors Affecting Performance

Factors that affect the performance of a milking installation are concerned with the cow, the number and organization of milking units and the man's routine. This can be understood by reference to Fig. 1 which shows the difference in work routine of the two basic types of milking parlour. The relationships can be summarized as follows:

1. INFLUENCE OF THE COW AND THE MILKING MACHINE

The number of cows milked with each unit depends on the time the unit is required for each cow (i.e., the unit time). This includes the total time that the machine is on the cows plus the time the unit is idle in respect of these cows. In practice the unit is idle between cows while the same routine of operations is carried out, and to estimate the unit time, a fixed value—depending on the type of parlour—can be added to the total milking time per cow. Fig. 1 shows the differences in unit idle times of the two basic types of parlour and reasonable values are 1.2 min in one stall/unit and 0.2 min in two stalls/unit parlours.

Thus, the number of cows milked per hour per unit can be calculated by dividing 60 by the unit time (UT) where unit time (min) is the average time the units are on the cows plus the average unit idle time.

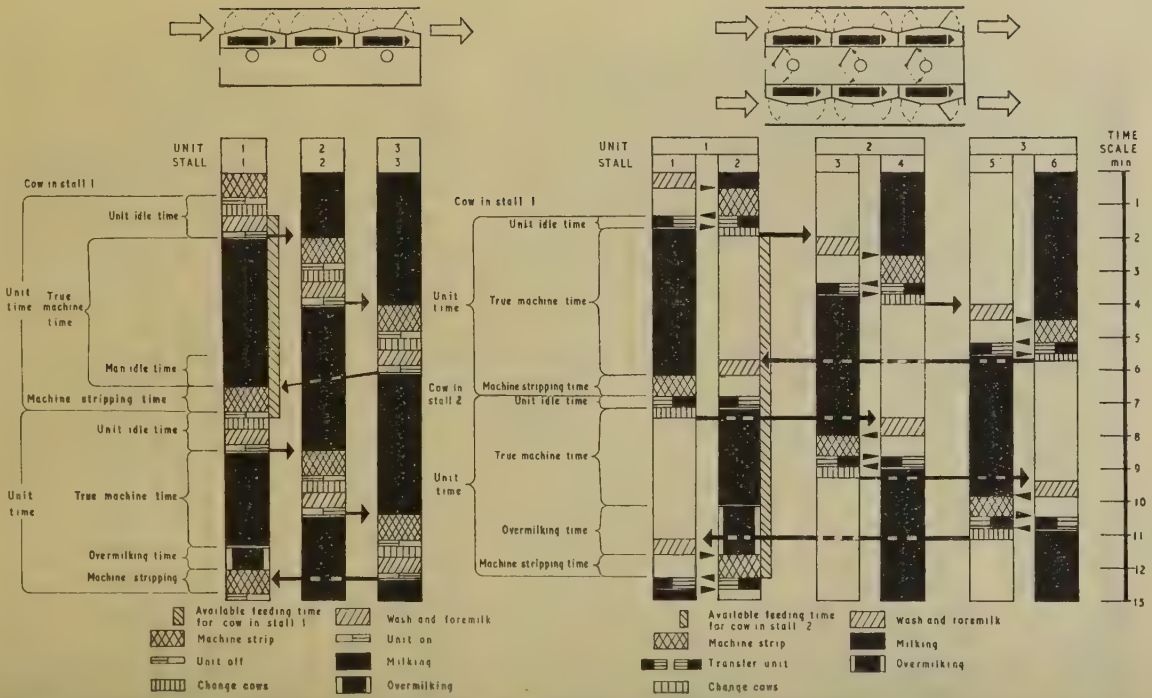

FIG. 1. Routine work and the factors which affect performance in one stall/unit and two stalls/unit parlours. The arrow shows the milker's sequence of movements during milking.

If more than one unit is used:

$$P = \frac{60\,N}{UT}$$

where P = performance or cows milked per man-hour
and N = number of milking units per man.

Estimates of standard milking times and yields per cow used in the calculation of parlour performance (i.e., cows milked per man-hour) in the previous article [1] were derived from the records of individual animals collected over the past ten years by the National Institute for Research in Dairying. These records show the relative stability of the milking rate of the individual, and the wide differences which occur between cows, but do not show what effect the between-cow differences have on the average machine time per cow in a particular herd. Machine time depends on the milk yield and the rate at which milk is removed from the udder, and, provided there are not large genetic differences in milking rate between herds, it should be possible to predict the average machine time per cow of a herd from the average yield per cow.

To check this hypothesis, the true machine times of each of the 766 cows in 20 parlour milked herds were measured at a morning and an evening milking. In this survey the machine time of each cow was from the start of milking until milk ceased to show in the inspection window of a Ruakura Milk Flow Indicator [2] Measurements of machine time are independent of the milker, and to estimate total milking time 0.4 min has been added as a reasonable allowance for the average time needed for machine stripping.

In these 20 herds the average herd machine time varied from 2.7 to 5.6 minutes and was proportional to the average milk yield per cow. After adding the standard allowance for stripping (0.4 min) the relationship between milking time per cow (min) and average herd milk yield (lb per cow at the milkings recorded) can be expressed by the formula

$$y = 0.164x + 2.33$$

when y = herd milking time per cow (min)
and x = herd milk yield (lb per cow).

It will be seen from Fig. 2 that a good prediction of machine time can be made from milk yield. In fact, the regression coefficient was 0.164 ± 0.004 and in this particular sample of 40 herd values predictions of average milking time from average yield would have been in error by more than 0.5 min in only three instances.

The value of this relationship is that it provides a quick and reasonably accurate estimate of average milking time from data that are readily available (i.e., average yield per cow). Unit time is obtained by adding the appropriate value of unit idle time to this estimate and from this the absolute performance of the parlour is calculated from the formula shown above.

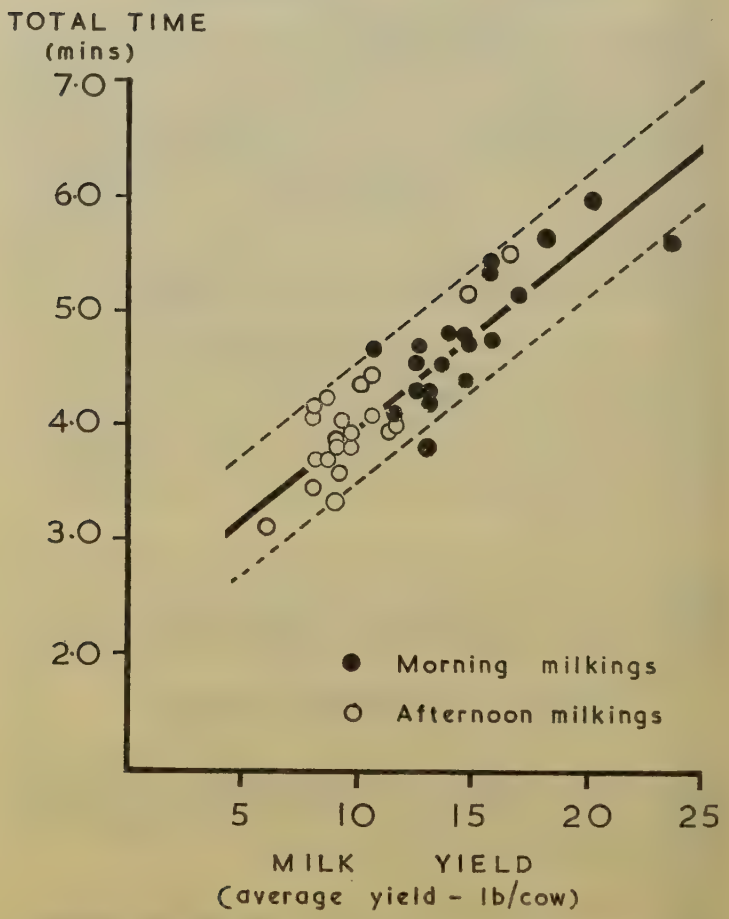

FIG. 2. The relationship between total milking time (i.e., machine time plus stripping time) and milk yield. In only 3 of the 40 cases would a prediction of average milking time, based on milk yield, have been in error by more than 0.5 min. (i.e., outside the dotted lines on the graph).

2. THE MILKER'S WORK ROUTINE

Provided that a man is fully occupied in routine work his performance (i.e., cows milked per man-hour) will be 60 divided by the average time spent working on each cow. This is independent of the number of milking units that he operates.

The existing data on well-organized work routines [3, 4, 5 and 1] suggest that routine times of $1\frac{1}{4}$—$2\frac{1}{4}$ min per cow can be achieved with systems of management suitable for this country. In practice it is not possible for a milker to spend all his time on routine work; at times he will be idle because of the unequal milking times of the cows in a herd. Also it is essential to allow time to deal with emergencies such as replacing teat cups that fall from the teats. The extent of this "planned idle time" has not been measured, but it has been suggested that it should not be less than 15 per cent of the milker's time [3]. The available work time (i.e., time available for the milker to do the routine work on each cow) must cover the work routine time plus an idle time allowance and in well-organized parlours from $1\frac{1}{2}$—$2\frac{1}{2}$ minutes should suffice. The number of cows milked per hour in a parlour can then be calculated by dividing the available work time per cow into 60 minutes. That is:

$$P = \frac{60}{AWT}.$$

Concentrate Feeding

From Fig. 1 it will be seen that the time available for feeding concentrates is much longer in 2 stalls per unit than in 1 stall per unit layouts. Because cows can be expected to eat dry concentrates at an average rate of 0.75 lb per minute [1 and 5], an estimate of the quantity that will be consumed by a cow while in a parlour can be calculated when the available feeding time is known.

Measurement of Performance

By combining the two relationships found above we have a simple formula that describes the relationship between performance and the milker's routine, the cows and the milking units in any type of installation. That is:

$$P = \frac{60\,N}{UT} = \frac{60}{AWT} \text{ and hence}$$

$$UT = AWT \times N,\ N = \frac{UT}{AWT} \text{ and } AWT = \frac{UT}{N}.$$

To avoid frequent calculation, Table 1 has been prepared. This gives the performance and the available work time per cow for 2-8 unit parlours over the complete range of unit times for herds with average yields of 5-25 lb milk per cow at a milking.

Table 1

The Relationship between performance of a Milking installation, unit time, number of units used and available work time.

The table is calculated from $P = \frac{60}{AWT} = \frac{60}{UT} \times N$

when P = cows milked per man-hour; AWT = the available work time (min); UT = the unit time (min); N = the number of units used. The figures in heavy type are the performance and available work times of all the necessary unit sizes of milking installation with the types of herds likely to be found.

TYPE OF INSTALLATION						NUMBER OF MILKING UNITS													
1 Stall/unit		2 Stall/unit		Cowshed	Unit Time	2		3		4		5		6		7		8	
YIELD*	C†	YIELD	C	YIELD	(MIN)	P.	A.W.T.	P.	A.W.T.	P.	A.W.T.	P.	A.W.T.	P.	A.W.T.	P.	A.W.T.	P.	A.W.T.
—	—	7	5.2	—	3.7	**32**	**1.9**	49	1.2	65	0.9	81	0.7	97	0.6	114	0.5	130	0.5
—	—	10	6.2	7	4.2	**29**	**2.1**	43	1.4	57	1.1	71	0.8	86	0.7	100	0.6	114	0.5
7	3.5	13	6.9	10	4.7	**26**	**2.4**	38	**1.6**	51	1.2	64	0.9	77	0.8	89	0.7	102	0.6
10	3.9	16	7.7	13	5.2	**23**	**2.6**	**35**	**1.7**	46	1.3	58	1.0	69	0.9	81	0.7	92	0.7
13	4.3	19	8.4	16	5.7	21	2.9	**32**	**1.9**	42	1.4	53	1.1	63	1.0	74	0.8	84	0.7
16	4.7	22	9.2	19	6.2	19	3.1	**29**	**2.1**	**39**	**1.5**	48	1.2	58	1.0	68	0.9	77	0.8
19	5.0	25	9.9	22	6.7	18	3.3	**27**	**2.3**	**35**	**1.7**	45	1.3	54	1.1	63	1.0	72	0.8
22	5.4	28	10.7	25	7.2	17	3.6	**25**	**2.4**	**33**	**1.8**	42	1.4	50	1.2	58	1.0	67	0.9
25	5.8	—	—	28	7.7	16	3.9	**23**	**2.6**	**31**	**1.9**	**39**	**1.5**	47	1.3	55	1.1	62	1.0
28	6.2	—	—	—	8.2	15	4.1	22	2.7	**29**	**2.1**	**37**	**1.6**	44	1.4	51	1.2	59	1.0
					9.0	13	4.5	20	3.0	27	2.3	33	1.8	40	1.5	47	1.3	53	1.1
					10.0	12	5.0	18	3.3	24	2.5	30	2.0	36	1.7	42	1.4	48	1.2

*YIELD—The average milk yield of the cows at a milking. (lb)

†C—The average quantity of concentrates that can be eaten while the cow is in the milking stall. (lb)

Cowsheds

Most cowsheds have a vacuum pipeline with a single cock between each pair of cows, the work routine follows a similar course to a 2 stalls/unit parlour. Machine milking performance can be similar to that achieved in milking parlours, if the routine work is limited to the tasks directly associated with milking and full use is made of a wheeled trolley to minimize the time spent carrying milk. A reasonable allowance for unit idle time per cow is 0.7 minutes and this value has been used in the table to place the average milk yields per cow opposite the appropriate unit times.

How to use the Table

The table can be used for two purposes. In conjunction with the principles outlined in the previous article [1] it can be used to calculate the correct unit size of milking parlour for particular conditions. Alternatively, it can be used to check the efficiency with which an existing installation is used.

EXAMPLE 1. CHOICE OF MILKING PARLOUR

A farmer has a herd of 50 cows with an average daily yield of 30 lb milk per cow, and an autumn calving season. What type of parlour would allow him to milk the 45 cows usually in milk in not longer than 1½ hours per milking, feeding up to 14 lb of concentrates per cow per day, using only one cowman?

We know:

(*a*) a rate of 30 cows/hour/man must be achieved,

(*b*) a 2 stalls/unit parlour is required because of the level of concentrate feeding.

If we assume the average yield of milk per cow at the morning milking is 19 lb, the correct size of parlour can be found from the table. From the row opposite 19 lb in the 2 stalls per unit column, it will be seen that this man *will* milk 32 cows per hour with a 6-stall 3-unit parlour if he can carry out his routine work in the available work time of 1.9 minutes.

EXAMPLE 2. CHECKING AN EXISTING SYSTEM

The farmer in example 1 takes the advice and a year later complains that he should have been advised to have a 4-unit parlour because he can milk only 23 cows per hour.

From the table we can see that if a man is milking only 23 cows per hour with a 6-stall 3-unit parlour, then his performance is limited by:

(*a*) a unit time of 7.7 min instead of the expected 5.7

or (*b*) an available work time of 2.6 instead of the necessary 1.9.

A few simple observations and measurements will determine which is responsible for the poor performance.

The first step is to find out whether the routine work takes 2.6 minutes.

If the man has no idle time then routine work is limiting the performance. If the milker is often idle, waiting for cows to be ready for stripping, then unit time is restricting performance. This is usually due to the milker's lack of skill (e.g., poor judgment of the time to start stripping), but very occasionally it will be due to slow-milking cows or a defective milking machine. The cause of high unit time can be determined with certainty only by measuring the milking rates of the cows.

It is interesting to note that if this farmer had used an 8-stall 4-unit parlour he would still milk only 23 cows per hour unless he could reduce his routine work time to below 2.6 minutes per cow. Furthermore, his unit time would have been 10.0 minutes, and therefore the overmilking about 4 minutes per cow per milking!

In checking the efficiency of an installation where more than one man is working, the calculations should be on the basis of the number of cows milked and units operated *per man*. Thus, if 2 men operated 6 units and milked 50 cows per hour the efficiency is calculated for 1 man operating 3 units and milking 25 cows per hour. Occasionally, values outside the range of the table will be needed (i.e., when 2 men operate 5 units). These can quickly be calculated from the original formula.

Conclusions

Using the principles and methods outlined in this and the previous article [1] it is possible to decide on the correct type of milking installation for a particular herd and to predict with reasonable accuracy the performance that will be achieved. If this performance is not achieved the table can also be used to diagnose the probable cause of the low throughput of cows. *The table should be used as a guide rather than as fixed values that must be achieved.* The figures in heavy type relate to available work time values of from $1\frac{1}{2}$-$2\frac{1}{2}$ minutes per cow and should cover most farm conditions and work routines in Great Britain. Until further data are available the performance of a milking machine installation can be regarded as satisfactory if it is within 5 cows per man-hour of that predicted from the table, provided that performance does *not fall below 20 cows per man-hour.*

ACKNOWLEDGMENT

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Scientific Principles of Livestock Feeding: Part I

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A CONFERENCE was held in Brighton on the 11th, 12th and 13th of November, 1958, at which the scientific basis of the feeding of farm animals was discussed in the presence of about three hundred persons drawn from the Research Institutes, Universities and Colleges, the Ministry of Agriculture, Fisheries and Food, the feedingstuffs industry, the veterinary profession and the farming community.

The conference, convened on the initiative of Sir Richard Haddon, was planned by a fully representative organizing committee under the chairmanship of Dr. D. P. Cuthbertson, Director of the Rowett Research Institute. This committee arranged for the presentation of ten main papers by experts well qualified to do so, and for the opening of discussions by others equally eminent.

The following notes are intended to bring out the main points of certain of these papers and it is hoped to continue with other papers in the next issue of the Review.

The Historical Development of Feeding Standards

C. Tyler, Reading University

Professor Tyler traced the development of standards from the "hay equivalent" of the early nineteenth century to the ideas now current. Comment is confined here to those which have survived today.

The "*total digestible nutrients*" (TDN) system used in the U.S.A. is not so fundamental as a net energy system, but it is convenient in practice because digestibility measurements are relatively easy to make. The TDN are calculated in the following way:

Digestible protein + digestible carbohydrate + digestible fibre + (digestible fat × 2.25).

Armsby's *net energies* were determined on planes of nutrition below the maintenance level. As the animal body converts energy more efficiently at low levels, it is hardly surprising that complete agreement is not obtained between Armsby's net energy values and Kellner's *Starch Equivalents* (also a net energy system) because the latter were determined at and above the maintenance level. Nevertheless, the two systems give results which often agree closely.

The usual Scandinavian *feed unit* is one kilogram of barley, corresponding to about 1.54 lb S.E., and, for the most part, other foods bear similar ratios to each other in terms of barley feed units as they do in S.E. values. Møllgaard has suggested the term NKF (net calories for fattening). Thus, 1 NKF produces 1 kcal in the form of body fat but, since milk production is a more efficient process than fattening, only 0.84 NKF is required to produce 1 kcal in the form of milk. Møllgaard has applied NKF to maintenance requirements and also to stock other than cattle.

Other concepts relating to *ballast* (indigestible organic matter), and to the need for deductions of calories in proportion to the weight of dry matter eaten, have been advanced to explain the failure of feeds to attain in practice the full calculated Kellner S.E.

On the question of protein, there is a general feeling that the best measure in the ruminant is *digestible crude protein* and not *protein equivalent*, although there is a reluctance on the part of some Scandinavian workers to allow anything for the ammonia nitrogen to be found in underheated silage. They also claim that there should be a deduction of one-quarter from the crude protein of roots.

However, in view of the ability of ruminal microbes to utilize even ammonia in the presence of adequate amounts of starch, the alleged worthlessness of the simpler forms of nitrogenous compounds is open to question.

Finally, one major difficulty for which no solution is yet forthcoming is that of individual variation, both in the composition of any one species of plant and in the efficiency of any particular animal in utilizing the plant. Tables of feedingstuffs' compositions and of feeding standards can only be used in a very broad way.

Feeding of Calves

J. H. B. Roy, National Institute for Research in Dairying

The viewpoint taken was not to consider what was the most desirable rate of growth, but rather what actual nutrients are required for given weight changes at stated weights and ages.

The appetite for dry matter per 100 lb live weight is highest in the younger animals according to the standards of Morrison and of Woodman, being about 3 lb at 100 lb live weight, and falling to 2.2 lb per 100 lb at 1,000 lb live weight.

Water consumption is greatly affected by the environmental temperature, the intake at 80°F being one-and-a-half times that at 50°F. However, other factors such as the intakes of dry matter, protein and salt are also involved. Generally it would appear that water consumption is a little over 10 lb per 100 lb live weight at 100 lb live weight and falls to about $7\frac{1}{2}$ lb per 100 lb at 1,000 lb live weight.

Energy maintenance requirements vary between about $1\frac{1}{2}$ lb S.E. at 100 lb and 6 lb S.E. at 1,000 lb live weight, and it is suggested that interpolation between these values should be used for intermediate live weights rather than adjustment by $W^{0.67}$.*

Maintenance plus 1 lb liveweight increase daily is estimated to require from about $3\frac{3}{4}$ lb S.E. at 300 lb to about $7\frac{1}{2}$ lb S.E. at 800 lb according to Winchester and Hendricks and by Woodman's standards, but by Eckles and Gullickson about 1 lb more S.E. would be required at the lower live weights, and $\frac{1}{2}$ lb more at the higher. For maintenance plus maximum gain (about 2 lb live weight daily) the requirement at 300 lb live weight would be from $4\frac{3}{4}$ to 6 lb S.E. according to different authorities and from $9\frac{1}{2}$ lb to $10\frac{3}{4}$ lb S.E. at 800 lb. Probably the lower range of figures, associated with $11\frac{1}{4}$ lb S.E. at 1,000 lb live weight, is adequate; it agrees closely with the Woodman standard.

The results of work on protein standards are even more variable than those on energy, and after reviewing the available information Roy makes tentative recommendations which are included in the following table:

*It is generally held that the energy requirements for maintenance are directly proportional to the surface area of the animal because heat is lost to the exterior mainly from the surface (apart from that in breath, urine and faeces). The surface of an irregularly-shaped animal is difficult to measure directly, but if the cube root of the weight is taken (thus reducing the animal to "one dimension") and this is then squared ("two dimensions" or "surface") an approximation is obtained which enables one animal to be compared with another "standard" animal, e.g., If W (lb live weight) is 1,000, then $\sqrt[3]{W}=10$ and $\left(\sqrt[3]{W}\right)^2=100$, i.e., $W^{\frac{2}{3}}$ or $W^{0.67}=100$. Similarly if W is 1331, the cube root is 11 and this squared is 121. If the energy for maintenance of the 1,000 lb animal is decided, then that for the 1,331 lb animal will be 1.21 times as great. Different workers have chosen different indices (logarithms) e.g., $W^{0.63}$ and $W^{0.74}$.

Suggested Allowances for Growing and Fattening Cattle (Dry Matter, Water, Energy and Protein)*

Live Weight	Dry Matter	Water (ambient temperature: 50°F)	Energy as S.E.			Digestible Crude Protein	
			Maintenance	M. + 1 lb L.W.I.	M. + 2 lb L.W.I.	M. + 1 lb L.W.I.	M. + 2 lb L.W.I.
lb	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*
100	3	10-20	1.9	2.8	4.2	0.35	0.55
200	6	20	2.8	3.7	4.9	0.50	0.70
300	8	30	3.5	4.7	5.8	0.65	0.85
400	11	40	4.0	5.5	6.7	0.75	0.95
500	14	47	4.4	6.0	7.5	0.80	1.05
600	16	53	4.9	6.5	8.4	0.85	1.10
700	17½	60	5.2	7.0	8.9	0.90	1.15
800	19	67	5.6	7.5	9.8	0.90	1.20
900	20½	73	5.8	8.0	10.5	0.95	1.25
1,000	22	80	6.0	8.4	11.2	0.95	1.25

(*Adapted from Table 6 of the original paper)

There is considerable disagreement between investigators as to the necessary levels for calcium and phosphorus, estimates of the latter in particular being very wide. The table below gives the intake requirements for maintenance plus 1 lb liveweight increase including an allowance for losses through non-absorption.

Live weight	*Gross Requirements for Maintenance + 1 lb L.W.I**	
lb	*g. CaO*	*g. P_2O_5*
100	6	11
200	8	17
300	13	23
400	17	32
500	21	38
600	24	42
700	29	46
800	35	50
900	42	54
1,000	52	58

*Adapted from Tables 1 and 2 of the original paper. Table 6 shows a narrower range of values commencing at 14 g. CaO and 18 g. P_2O_5 at 100 lb live weight and finishing with 36 g CaO and 51 g. P_2O_5 at 1,000 lb.

Magnesium requirements of calves on milk have been estimated at between 15 and 20 mg per lb live weight, but allowances for older animals have not been fully worked out because much variation is caused by the nature of the ration and of the animal itself. Sodium and chlorine needs are met by 0.5 to 1 per cent of NaCl in the concentrates.

With regard to trace elements, suggestions are made at the end of

Marion A. Watson

SYMPTOMS OF VIRULENT CEREAL YELLOW DWARF ON OAT, RYEGRASS AND BROMUS SPP.

In each photograph, a healthy plant is shown on the left; an infected one on the right, the latter having been experimentally infected in the glasshouse.

Top left: *Avena sativa* var. Blenda. **Top right:** *Lolium perenne* var. S.23.

Bottom left: *Bromus sterilis*. **Bottom right:** *Bromus arvensis*.

PLATE I

RYEGRASS MOSAIC IN BLENDA OAT

Healthy plant on left; infected one on right.

STRIATE MOSAIC INFECTED WHEAT

—collected in the field at Rothamsted.
Healthy plant on right; infected one on left.

PLATE II

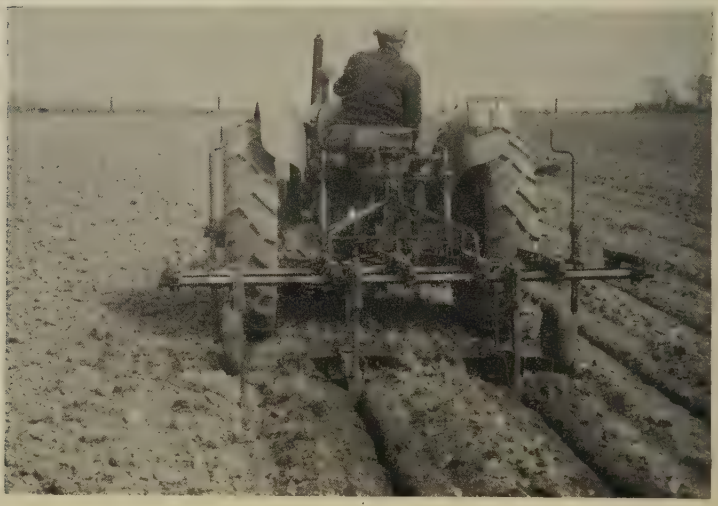
Photos : Marion A. Watson

SYMPTOMS IN INDIVIDUAL LEAVES OF THE PRINCIPAL HOST PLANTS

Ryegrass mosaic in ryegrass. Wheat striate mosaic in wheat. Barley stripe mosaic in barley.

PLATE III

COMMERCIAL PRACTICE IN ROSE-GROWING NURSERIES IN THE EAST MIDLANDS REGION (See pp. 132-8)



Top: Preparing "grip" for hand planting.
Bottom: Planting machine, showing stocks held in "fingers".

this section, but quantitative requirements for copper are difficult to define owing to the interaction of other elements, and care has to be exercised to avoid toxic doses when treating known cases of deficiency.

Vitamins of the B complex are formed in the rumen when it becomes functional. Before that they are supplied by milk. Vitamins A and E are normally present in green foods in sufficient amount. Vitamin D is formed by sunshine direct on the animal and on hay; but winter-born calves, and hay made in a bad season, can be deficient, and a supplement may be necessary.

Suggested allowances for trace elements and vitamins per 100 lb live weight are:

	mg	*i.u.*
Cobalt	0.15	
Copper	12	
Iron	150	
Manganese	25	
Carotene	15	
(or Vitamin A)	3	
Vitamin D	—	450
Vitamin E	150	

Suggested Requirements of Pregnancy

Energy: Estimates of the extra daily requirement of the cow during the last three months of pregnancy vary from 0.5 lb S.E. to 1 lb S.E. The latter figure is to be preferred.

Digestible Crude Protein: 0.5 to 0.6 lb per day is a reasonable estimate.

Minerals: 40 g CaO, 35 g P_2O_5.

Vitamins: Three times the non-pregnant allowances.

Roy concludes that precise requirements for a particular nutrient can rarely be given. Although few standards have been in agreement, all can be supported by practical evidence, but their limitations should be recognized. A great increase in efficiency of production would result if mobile weighing scales and cattle crushes could be provided and taken round farms to obtain evidence of growth rates on known rations.

Beef Cattle

T. L. Dodsworth, North of Scotland College of Agriculture

Dodsworth made the point that feeding standards are only useful as rough guides to average food allowances for large numbers of animals, and that the matter was further complicated by the fact that beef cattle are fed to appetite in winter on the bulk feed appropriate to the locality. Their role as scavengers of straw and beet tops and as manure machines is important. Whatever progress they make on this basal bulk can be stepped up by appropriate concentrate feeding to make them ready for the market at a chosen date. A further point is that the nutritive value of bulky roughages is very uncertain and may vary considerably according to season and locality.

MATURE CATTLE IN WINTER

The moisture content of the food is important, because if the overall dry matter content of the ration is not at least 25 per cent, the consumption of dry matter will fall short of the commonly accepted $2\frac{1}{2}$ lb per 100 lb live weight. Cattle of 9 cwt fed twice daily will eat about 100-112 lb of food and will apparently be satisfied by this weight even if the dry matter is lower than is desirable.

Liveweight gains often fall below the calculated expectations because there is an initial settling-down period, particularly with newly-purchased cattle just after tying-up for fattening, during which live weight may actually decrease. There is room for investigation into methods of management to eliminate this.

When actual liveweight gain was expressed as a percentage of calculated live weight for 138 animals, the results varied from 56 to 380 per cent and two-thirds of the animals exceeded 100 per cent. Similar results were obtained when calculations were made on 30 trials. These results showed that the needs for maintenance and/or production tend to be over-estimated or the S.E.s of the foods used are under-estimated, or both. "Individuality" may be advanced to explain these findings.

"Individuality" as applied to the animal can cover differences in hormone balance (affecting the efficiency of conversion), in mineral status, and variations in requirements. Progeny-testing is greatly required.

"Individuality" among feedingstuffs is such that Dodsworth expressed the opinion that S.E.s and other values of the feeds commonly used in a locality *should be estimated in that locality*. Thus, the kernel content of oats may vary by 10 per cent according to variety and locality, and Dodsworth's own experience confirmed the view that roots grown in higher latitudes are more nutritious. He found an increase of one-sixth in the S.E. of swede dry matter in Aberdeenshire over that given in standard tables. Finally, since the S.E. of a feedingstuff is influenced by the nature of the accompanying feedingstuffs it would be well to make the estimations on standard-type rations.

Lower levels of performance can be expected from cattle kept loose in yards than from those tied up in sheds.

The suggestion in the Ministry of Agriculture's Bulletin No. 48 that 0.95 lb of digestible crude protein is sufficient for fattening cattle that are putting on 2 lb live weight daily is accepted by Dodsworth, who points out that if the animal's requirements for S.E. are to be fully met it is difficult to plan a ration which does not exceed this amount of protein.

BABY BEEF

If the requirement of S.E. for maintenance is taken as being proportional to $W^{0.75}$, then the same S.E. per lb gain as is suggested for store cattle should suffice. An increased protein allowance is likely to be

required, however. The problem should be further examined to establish the animal's requirements, which from 6 to 18 months will depend upon the previous plane of feeding.

FINISHING ON GRASS

Scientific principles are difficult to apply because exercise, food value of the sward, and weight eaten can all vary greatly. Again, scouring, which sometimes takes place on turning out to grass, must be controlled if the finishing date is not to be retarded. There is some evidence that supplementation with concentrates is uneconomic on good grass.

Dairy Cows

K. L. Blaxter, Hannah Dairy Research Institute

It is well known that the nutritive value of a feedingstuff can vary from one sample to another, and it is also true that cows differ in their efficiency in converting food. But detecting these two sources of variation is often impossible. Hence, the approach to dairy cow feeding has come to be one in which average requirements, nutritive values and responses are assumed, but also one in which adjustments are made after seeing the practical results. Moreover, margins of safety can be introduced to cover the poorer performers.

APPETITE

The appetite of milking cows greatly exceeds that of beef steers of the same size. In the same cow intake of feed dry matter may vary from 18 to 40 lb on different rations depending upon quality, when quality is defined as the concentration of energy-yielding nutrients in the dry matter. It is thought that the indigestible matter, or "ballast", produces a sensation of repletion and, according to Lehmann, the quantity of ballast for a 10 cwt cow is about $9\frac{1}{2}$ lb. This means that when such a cow has consumed enough food to yield $9\frac{1}{2}$ lb of indigestible material each day, it loses the desire for further consumption. The smaller the percentage of ballast in a ration, the more ration that will be eaten. Blaxter's own work with sheep shows that appetite is not governed only by the daily intake of dry matter or by the weight of indigestible matter excreted daily, but that the bulk of food in the animal—the "fill"—is decided by these two factors plus a third, namely, the rate of passage of the food. He suggests that the present standards for appetite, based on dry matter only, tend to ascribe a greater concentrate-replacement value to low-quality farm-grown roughages than in fact they possess.

ENERGY REQUIREMENTS

Experiments with 21 cows (mostly dry though sometimes in calf but rarely in milk) showed that, for the standard 1,000 lb cow, the requirement for maintenance averaged 5.27 lb S.E. with a standard deviation

of ± 0.77. The amount of S.E. to be supplied so that only 1 cow in 20 would be underfed would be 6.61 lb. This "margin of safety" is statistically defined and is limited only by the small number of cows used in deriving it.

The net energy of milk is closely related to its fat content and only slight errors are involved in assuming that it is directly proportional to the fat percentage. Thus, the net energy of 4 gal milk with 3.5 per cent fat is approximately the same as that of 3.5 gal of milk with 4 per cent fat.*

It is convenient therefore to take fat-corrected milk as standard because other milks can readily be re-calculated in terms of it. Making use of the known calorific value of fat-corrected milk and of the relative efficiency of milk production as compared to fat production (1 to 0.83 according to Møllgaard) it can be calculated that 10 lb of such milk require 2.63 lb S.E. on average (range: 2.56 to 2.82). Similar work in the U.S.A. gave values from 2.42 to 2.53. These values apply to rations in which protein supplied about 20 per cent of the total energy, i.e., the normal S.E. to D.P. ratio. When the protein contribution was reduced to 12 per cent, the S.E. requirement rose to between 2.66 and 2.98 lb per 10 lb milk and a reduction to 4 per cent raised the requirement to 4.11 lb S.E.

Analysis of the results obtained with normal protein intakes shows a requirement of 2.67 lb S.E. with a standard deviation of ± 0.14. Calculated with a safety margin so that only 1 cow in 20 would fail, the standard becomes 2.9 lb S.E. The accepted British standard for 4 per cent milk is 2.6 compared with 2.8 and 2.9 for America and Scandinavia respectively, and therefore the introduction of the margin of safety would bring the British standard more into line with the others.

The situation is made more complex, however, by other considerations. The law of diminishing returns acts so that food is less efficiently used at higher levels of production than at lower. Further, this drop in efficiency is more marked with foods of low quality than with high-quality foods. Then again, ruminal fermentation takes different paths with different foods and the end-products of each differ in their relative efficiencies for maintenance and for production.

Unpublished work by Blaxter shows that the higher the lactation yield when the cow is fed to standard, the greater is the response to additional feed when the response is expressed as lb milk per lb S.E. Furthermore, steaming-up results in a yield increase of about 1.7 to 2.0 lb milk per lb of S.E. given before calving.

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*The formula for correcting a milk yield to the standard 4 per cent milk is:
lb of 4 per cent fat-corrected milk = (0.4 × actual milk yield in lb) + (15 × actual fat yield in lb).
Hence 40 lb of 3.5 per cent milk = (0.4 × 40) + (15 × 1.4) = 37
The error in assuming 3.5 gal in place of the correct 3.7 is therefore about 6 per cent.

PROTEIN REQUIREMENTS

Requirements vary with the quantity of dry matter consumed. It is suggested that digestible crude protein should be used in place of protein equivalent and this is applied in the following table (adapted from Table 5 of the paper). As before, the safety margin is such as to include the needs of 19 out of 20 animals.

Daily Protein Requirements of a 1,000 lb Cow Producing 4 per cent Fat-corrected Milk

	Dry Matter Intake	Digestible Crude Protein Required	
		Mean and Standard Deviation	With Safety Margin
	lb	*lb*	*lb*
Maintenance	20	0.46 ± 0.04	0.53
	25	0.51 ± 0.05	0.60
M + 1 gal	25	0.98 ± 0.08	1.11
	30	1.02 ± 0.09	1.17
M + 2 gal	30	1.50 ± 0.13	1.72
	35	1.55 ± 0.13	1.77
M + 4 gal	30	2.43 ± 0.22	2.80
	40	2.54 ± 0.23	2.93

It will be seen that there are no real changes from present standards, even when safety margins are included. The present M + 2 standard of [0.6 + (0.5×2)] lb P.E., i.e., 1.6 lb P.E. would be 1.75 to 1.9 lb if expressed as D.C.P., and M + 4 requiring 2.6 lb P.E. would have this expressed as about 3.0 D.C.P.

MINERALS AND FAT-SOLUBLE VITAMINS

More investigational work is necessary before allowances for these can be stated as precisely as those for energy and protein.

NOTE:

In the subsequent discussion, the addition of margins of safety was criticized on the grounds (*a*) that if we already have a reliable statistical mean we ought to accept it as such without embellishment, and (*b*) that the use of safety margins penalizes the work of the efficient cow. We ought to cull the inefficient ones, not pamper them. Blaxter maintained, however, that the cow's yield would usually adjust itself upwards on account of the higher plane of feeding and this would be desirable if the return produced were economic.

At a later stage Blaxter suggested that sliding scales could well be applied to various levels of milk yield. Tentative suggestions were: 2 lb S.E. per gal for under 2 gal, 2½ lb S.E. per gal for 2½-3 gal, but a yield of 6 gal might require 3¼ lb S.E. per gal. It was hoped that collaborative feeding trials would be arranged to test this idea.

Estimated Quantities of Lime needed in the United Kingdom on Agricultural Land (excluding Rough Grazings)

E. ROBERTS

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A SUMMARY of estimates of lime needed in England and Wales was published in Volume 2, No. 8 (Summer 1950) of the N.A.A.S. QUARTERLY REVIEW. Since that time the equivalent of 36 million tons of calcium carbonate has been applied in England and Wales and another 12½ million tons in Scotland and Northern Ireland.

The Liming Committee of the Advisory Soil Chemists' Conference has again made an assessment of the quantities of lime needed on agricultural land excluding rough grazings, by relating the percentage of soil samples in the different lime requirement categories to the acreage of crops and grass.

This method will provide only an approximate estimate of the total lime requirement for any N.A.A.S. region. The degree of accuracy will depend on how representative the soil samples are for each county within the region. The estimate of lime requirement for each county—derived from the percentage of soil samples analysed which fall into different lime requirement groups—has been compared with the lime requirement of about sixty farms chosen at random for the Survey of Fertilizer Practice, and the results indicate that the sampling is, in fact, reasonably representative.

Estimated requirements, the previous assessment and the tonnage applied during the eight-year period between the two assessments are as follows:

Region	1950 *Assessment* (*In thousand*	1958 *Assessment* *tons* $CaCO_3$)	*Usage*
Northern	4,840*	2,062	4,378
Yorks. & Lancs.	3,160*	2,000	5,098
W. Midland	3,350	2,223	4,816
E. Midland	2,950	1,726	4,300
Eastern	1,950	2,256	5,214
S. Eastern	3,550	2,792	3,438
S. Western	5,000	4,104	5,028
Wales	3,200	1,637	3,484
Scotland	8,000	7,700	9,926
Northern Ireland	4,000	3,542	2,496
Total England and Wales	28,000	18,800	35,756
Total United Kingdom	40,000	30,042	48,178

*Adjusted to present Regional Boundaries.

Changes in the methods of assessment probably account for some of the varying regional differences between the two assessments. In the Eastern Region, deeper ploughing of peats and the cultivation of large acreages of other acid peats will partly account for the present assessment being higher than that of 1950. At present 6 tons per acre of $CaCO_3$ is being recommended on the more acid peats compared with 4 tons per acre in 1950. Heavy usage of fertilizers in this region may also be a contributory factor, information suggesting that about 1 cwt of $CaCO_3$ is lost for each cwt of ammonium sulphate used. In Northern Ireland it is believed that the previous assessment was rather too low.

Estimated Lime Losses

The greatest loss of lime from the soil occurs by leaching, and the amount lost will depend on the amount of free calcium carbonate present, texture of the soil and the annual rainfall. While various workers have shown that up to 10 cwt of calcium carbonate can be lost by leaching in soils containing high amounts, the average loss probably varies from about $1\frac{1}{2}$ cwt on acid soils (with low exchangeable calcium) to about 4 cwt calcium carbonate on medium loams under arable cropping.

It is difficult to give a precise figure for the overall loss of lime due to the use of ammonium sulphate, but assuming this fertilizer accounts for two-thirds of the approximate annual use of 300,000 tons of nitrogen in England and Wales, the annual consumption of ammonium sulphate will be in the region of 1 million tons, which will cause a loss of approximately 1 million tons of calcium carbonate.

Loss of lime from the sale of cash crops, stock and through grassland utilization accounts for only a small proportion of the annual losses and amounts to around 200,000 tons.

Dr. G. W. Cooke estimates the total annual losses as:

	000's *tons* $CaCO_3$
By leaching	2,450
By use of ammonium sulphate	1,000
By sale of cash crops	12
By sale of stock	54
Through grassland utilization	124
Total losses (England and Wales)	3,640

This figure gives an average loss per acre of 3 cwt calcium carbonate which agrees with the generally accepted figure of 1.5 cwt CaO.

Subtracting the difference between the two assessments from the amount applied and dividing this by the acreage of crops and grass gives an annual loss per acre of 1.8 cwt CaO.

At the present rate of liming the overall deficit of lime is being reduced in most regions, and if this is maintained then a satisfactory lime position should be attained within a reasonable time.

The Work of the Analyst

A. J. CAVELL

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OF ALL the science specialists in the N.A.A.S. the analyst has the fewest personal contacts with the farming community. His work is confined to Regional Headquarters where he is concerned with making measurements, in a specialized laboratory, on a wide variety of agricultural materials. Over twelve months, these probably include all types of feedingstuffs, fertilizers, soils, plant materials and many types of farm produce. The laboratories are equipped for the analysis of practically everything that the farmer handles, and much of the advice that he receives on materials sent in for chemical examination is based on the results of analyses carried out in the laboratories.

Many of the problems that face the analyst in the N.A.A.S. are general ones, common to all analysts, whether they are dealing with paints, disinfectants, foodstuffs, textiles or soils: in addition, each material presents problems peculiar to itself.

General Problems

The measurements that an analyst can make are limited by the equipment at his disposal, and the measurable properties of the material or its derivatives being examined: it follows, therefore, that it is often necessary to carry out a number of chemical conversions, or physical separations, before a measurement can be made. Thus, in the determination of total nitrogen in soil, the soil is digested with acid to remove organic matter and to convert, quantitatively, nitrogenous material to ammonium sulphate: the ammonia, which is easily measurable, is separated by steam distillation and measured either by a volumetric titration of its alkalinity, or by other means. Each of these steps may introduce an experimental error which cannot be reduced below a certain minimum, however carefully the analyst works. A knowledge of the experimental error inherent in a laboratory method enables the analyst to avoid giving results to a degree of arithmetical exactness not possible to achieve in practice. It is usual nowadays for a statistical appraisal of any new analytical method to be carried out by its author and for the coefficient of variation to be given. The choice of a method may depend on the reproducibility it gives. As a simple illustration, let us consider the value of a method that gives a figure of 0.21 per cent for the nitrogen content of a soil actually containing 0.20 per cent of nitrogen. The laboratory experimental error of 0.01 per cent, equal to 100 p.p.m of nitrogen in the soil, is roughly the amount of nitrogen that would be added to a soil by an application of 10 cwt of sulphate of ammonia per acre. It is unlikely, therefore, that results obtained with such a method would be suitable for the detection of small additions of nitrogeneous fertilizers, and an alternative method would be sought.

The ability to convert a substance to another which has measurable properties does not ensure that an assay can be made: a conversion will be valueless unless the reagents and apparatus available are sensitive enough to make measurements possible. In normal practice this means that many otherwise reliable methods are unsuitable because the concentration of the substance being measured falls below a certain limit. For example, a gravimetric method quite suitable for the assay of copper alloys could not be used to estimate 1 p.p.m of copper in a small volume of a soil extract.

THE SEARCH FOR REAGENTS

As colorimetric methods are usually more sensitive than gravimetric and volumetric methods, there is a constant search for reagents that will quantitatively develop stable colours. By the use of such reagents as dianthrimide and waxoline purple, it is now possible to estimate very small quantities of boron in soil extracts. Unfortunately, very few of the organic reagents available are specific: colours are usually produced by materials other than the one to be measured. The analyst may therefore have to carry out a lengthy preliminary separation before a sensitive colorimetric method can be applied. If, for example, titan yellow is used to determine magnesium in a soil extract, interference can be expected from calcium, cadmium, nickel, cobalt, aluminium, zinc and tin: aluminium reduces the intensity of the red given by magnesium, calcium increases it.

The analyst therefore searches for masking agents which combine with the unwanted substances that interfere with the colorimetric method but which do not affect the substance to be determined. Phosphoric acid may be used in this way to eliminate the interference of iron in the determination of manganese as permanganate.

Specific Problems of the Agricultural Analyst

Much advice on the quality of soil is given by agricultural advisory services throughout the world, and in this country alone, hundreds of thousands of soil analyses have been carried out since the N.A.A.S. was formed. For soil analysis to be of practical value to agriculture, there must be an established relationship between the measurements that can be made in the laboratory, field observations and the information required by the farmer.

Manurial field experiments have ascertained the relationship between the empirical laboratory measurements, such as the measurements of phosphorus and potassium in soil extracts, and the availability of those nutrients to the plant. Laboratory measurements on other soils of the same type from other sites can thereafter be used to assess the available nutrients present and to provide the farmer with information about the fertility of his soil.

ASSESSING "AVAILABLE" PHOSPHORUS

The total amount of phosphorus present in a soil can be determined accurately: unfortunately it is not a measure of the amount available. Dyer was the first analyst in this country to use a selective extractant, and he found that the acidity of the root sap of over 100 different plants, expressed as citric acid, averaged 0.9 per cent. He therefore suggested that 1 per cent citric acid might be suitable as an extractant for available phosphorus, and, by examining soils undergoing fertilizer trials, he was able to show that differences in fertilizer treatment were reflected in the phosphorus extracted. It was concluded that soil containing less than 0.01 per cent of phosphorus (as P_2O_5) soluble in 1 per cent citric acid was probably deficient in phosphorus available to the plant.

It may be noted that other acids of strength equivalent to 1 per cent citric acid do not extract the same amount of measurable phosphorus. It so happened that the choice of 1 per cent citric acid enabled measurements to be made in the laboratory with the methods known, and equipment available, in 1890. Its selection by Dyer was indeed fortunate.

The differences in the power of different acids to extract measurable phosphorus may be related to the differences in the power of the soil to absorb phosphorus from the various acid extracts. Thus the analytical data recorded by Dyer were the differences between the phosphorus extracted by 1 per cent citric acid and the phosphorus absorbed from the 1 per cent citric acid extract. These measurable results may be compared so long as soils of the same type are examined, but, unfortunately, standards found for one soil may not apply to another type of soil.

If, for example, the standards applicable to non-calcareous soils, when acetic acid is used as an extractant, are applied to Lias clays, soils known to be in need of phosphatic fertilizers may be judged to be rich in available phosphorus.

Citric acid is now only one of many empirical extractants that can be used: the introduction of sensitive colorimetric methods and the advances in instrument design have enabled other extractants to be used. 0.5N acetic acid and Morgan's reagent extract only about a half and one-twentieth respectively of the measurable phosphorus extracted by citric acid. Solutions of ammonium molybdate, sodium bicarbonate, lactic acid, sulphuric acid and buffered perchloric acid are among the many others which have been proposed.

The number of proposed empirical laboratory methods indicates that assessment of "available" phosphorus from a single laboratory measurement is not easy: indeed the use of the term "available" for the variable amount measured when different extracts are used tends to oversimplify the nature of the problem. Plants may not be able to utilize all of the phosphorus present: they may vary in their power to absorb phosphorus: some of the phosphorus in a soil may be held in an organic form. Attempts have been made to measure the various phosphorus

fractions in soil and to assess the total availability by reference to the amount of each type present. Such work has been hampered by the time-consuming laboratory work that it involves.

The N.A.A.S. Analysts' Conference has arranged for collaborative work on such general problems to be carried out in all N.A.A.S. laboratories, and individual analysts have studied particular problems that have arisen in the course of their work. Since the 1st Annual Conference in 1950, over 120 technical papers containing data valuable to the specialists have been prepared. They range from reports on International Congresses to the determination of trace elements in soils.

Laboratory analyses have been made on reference soils taken from the experimental plots planned by the Soil Chemists so as to be on suitable sites throughout the country. As the effects of applications of fertilizers to these soils are known, it is hoped that these analyses will enable the general relative value of various empirical methods to be assessed. Over two-hundred reference soils have already been studied.

DETERMINING THE LEVEL OF AVAILABLE COBALT

The simple concept of availability has been used very successfully in studying soils on which pining diseases occur. Since the connection between pining and the cobalt content of the diet has been established, it is possible to predict that, if cobalt is not available in the soil on which sheep are pastured, the animals will not thrive. It has been found that the cobalt extracted from certain soils with a dilute acid is not only related to its availability to the plant but is measurable with the analytical methods now available. A laboratory analysis can, therefore, establish the level of available cobalt. This was not possible until the discovery of sensitive colorimetric reagents, and the development of suitable analytical methods enabled available cobalt in soil in the order of 0.25 p.p.m to be determined. The level for cobalt in herbage is even lower, about 0.1 p.p.m.

Extraneous contamination often presents problems to the agricultural analyst. As the total cobalt in normal soils may amount to 30 p.p.m, it is necessary to remove all soil from plant material on which a cobalt determination is to be made. If 0.1 per cent of soil is present as extraneous matter it may increase the cobalt content of herbage from a low level to a more normal level.

RECOGNIZING DEFICIENCY OF AVAILABLE MANGANESE

Recognition, by chemical means, of soils deficient in available manganese is complicated by the various forms of the element that may be present. Manganese may be present as the bivalent exchangeable form and as the higher oxides which, in the presence of organic matter, may be reduced during laboratory manipulation. Pot experiments have shown that even the form in which higher oxides are present is important: oats and peas can obtain manganese much more readily from

manganite than from hausmannite. Analytical methods are now available which overcome even these difficulties.

BUFFERED SOLUTIONS

It is possible to prepare solutions of chemicals having intensities of acidity (or pH values) which do not alter greatly when additions of lime are made: such solutions are known as buffered solutions. Soils exhibit this characteristic to varying degrees, depending on the proportion of sand, grit, clay, organic matter, etc., present, and this variation in the buffering capacity of soils of different soil types may influence the choice of laboratory methods. An elegant empirical method of assessing the lime requirement of soils is based on pH measurements. It depends on the knowledge of the depression of the pH of a standard buffer solution which occurs when soil of "average" buffer capacity is shaken with it. The natural variations in soil make the use of such a method with unknown soils of doubtful value, but it can be used with confidence with those soils having a suitable buffering capacity.

Farmers refer to soils of different texture as light, heavy or chalky, but before these qualities can be measured in the laboratory they must be defined in measurable terms. Light, heavy and chalky soils are relatively rich in sand, clay and chalk respectively; hence, if sand, clay and chalk are suitably defined, measurements can be made and soil composition can be expressed in units that makes comparison on a basis of texture more precise.

A DEFINITION OF SAND, SILT AND CLAY PARTICLE SIZES

The carbonate, which all chalky soils contain, can be identified and measured. Sands and clays are not of constant chemical composition, and difficulties arise if attempts are made to define them in chemical terms; they have been given arbitrary definitions. Under the international system now in general use, coarse sand, fine sand, silt and clay have defined particle size limits of 2.0-0.2 mm, 0.2-0.02 mm, 0.02-0.002 mm and under 0.002 mm respectively. Formerly, a fine sand in this country and in the U.S.A. had particle size limits of 0.04-0.16 mm and 0.10-0.25 mm respectively.

With the aid of these definitions, the percentages of chalk, sand and clay in any soil can be determined in the laboratory and the relationship between the results of mechanical analysis, which consists of grading the particles in a soil into size groups, and texture, can be established.

Agriculturists appreciate that the structure of some soils is better than others; before an assessment of the quality of the structure of a soil can be made in the laboratory, the concept of a good structure must be defined in such a way that its quality can be measured with laboratory equipment. Although a considerable amount of work has been done on soil structure, a suitable definition, applicable to all soils, is still being sought.

Analysis of plant materials has its own problems: the method that can be used may depend on the type of plant and the ratio of the various elements normally present. Thus, a method suitable for the determination of normal amounts of calcium (1 per cent) and magnesium (1 per cent) in sugar beet leaves may not be applicable to kale leaves normally containing about 3 per cent of calcium and 0.1 per cent of magnesium. The known ubiquitous presence of phosphate in plant materials has prevented the adoption of methods which are excellent in its absence. The unexpected presence of abnormal quantities of some naturally occurring element, e.g., manganese, or of a spray residue, e.g., copper, can also present problems in the analytical laboratories.

Newer Problems

Whilst many old problems have been overcome, the recent use of chemicals, such as nitrofurazone, in feedingstuffs, and as fungicides, herbicides, repellents, seed protectants, etc., has presented other problems to the analyst.

Most pesticides are probably toxic to man and their indiscriminate use is undesirable. The analyst may, therefore, be asked to examine foodstuffs to find out if spray residues are negligible. Frequently no adequate analytical techniques are known, and many of the existing methods are lengthy, but the completion of such an analysis does bring to the analyst a sense of achievement and makes the exacting care that has to be taken seem worth while. Safe limits are not easy to define, but most countries have established standards: in France limits for BHC in grain and flour have been set at 5 p.p.m. and 1 p.p.m. respectively. Limits, such as 7 p.p.m. for DDT, 5 p.p.m. for 2,4-D, 1 p.p.m. for parathion, 0.3 p.p.m. for chlordane and 0.1 p.p.m. for aldrin, provide a fascinating challenge for the analyst to meet in the future.

CORRECTION

N.A.A.S. QUARTERLY REVIEW No. 42

CROP HUSBANDRY NOTES

Page 79, *3rd paragraph, last line should read:*

". . . towards **lower** responses in high rainfall areas ".

Farm Management Notes

K. DEXTER

Ministry of Agriculture, Fisheries and Food

Farm Management Analysis

What use can a farmer make of his profit and loss account? Is it just a necessary evil to satisfy the Inspector of Taxes or can the farmer put to good use the accounts, for the preparation of which he is paying his auditor in any case? These pertinent questions are asked by A. G. Jeffrey in a Ministry Bulletin: *Records and Accounts for Farm Management* [1]. The extra effort required to keep separate records of seeds and fertilizer purchases, of machinery and equipment repairs, etc., is worthwhile if an accurate picture of the farm's efficiency is to be obtained. With this bulletin at his elbow, a farmer should have no insoluble problems either over his own book-keeping or in the instructions he gives his auditors. Mr. Jeffrey has written a definitive study, both on farm accounting and on the use which can be made of the accounts. He makes an exhaustive review of performance measures available to the farmer, including those which are at present widely used in the advisory services.

Labour efficiency and gross output per £100 of labour are examined critically, and possible reasons given for both high and low gross output and for puzzling results from particular measures of labour efficiency. If crop and livestock yields are high, more labour than that provided for in the standard requirements may be efficiently used. Conversely, with low yields, gross output per £100 labour will tend to be low even if the labour employed is reasonable according to standard requirements.

The bulletin presents a careful and clear exposition of accounting practices for management purposes, but more attention might have been paid to less formal types of analysis. Without delving very deeply into the sphere of enterprise efficiency it should still be possible to apportion roughly the chief items of cost (labour, feedingstuffs, transport, etc.) to the various livestock enterprises, and to set them against the appropriate sales. This short-cut analysis is well worth while if it enables the farmer to find out quickly if the beef cattle are losing the money made on the sheep. Rapid pinpointing of an offending enterprise by this method could sometimes obviate the need for a detailed management analysis of the whole farm business.

DIFFERING PRACTICES IN THE U.S.A.

A group of European advisers discuss an alternative approach to farm management analysis in a report [2] of some current practices in the United States. While not denying the usefulness of accounts, the methods of farm management analysis on which it concentrates tend to require the minimum of records from the farmer. The report is a detailed study of American farm management advisory work as it is carried on in three mid-western states. A good deal of the report is concerned with

the training of extension workers and the planning of extension programmes. There is also an interesting appendix which contains a sample syllabus used for group meetings on farm management for farmers. In this sphere it is interesting to note the emphasis placed on the farm family as a unit and insistence on carrying planning help into what would often be regarded here as an entirely private province. Such questions, contained in the sample syllabus, as "What changes might be made that would add to your family's more comfortable living?" are symptomatic of this "social" attitude. One anomaly of this approach is that it departs from the concept of the farm as a business. Although individual decisions are bound to be influenced by personal preferences and differing concepts of farming as a way of life, it may be dangerous to encourage this element when making decisions, as opposed to the farm management aim of maximum profits based on economic facts.

On the more formal aspects of farm management the report describes in some detail the varying emphasis of the "farm business method" and the "programme planning" method of farm management analysis. The "farm business method", which is the usual approach in this country, regards the farm as one productive unit until a late stage in analysis. Making a logical progression from considering the size, organization, etc., of the farm business, it interprets the results with the help of average or premium standards. It is in planning future developments of a farm business that this form of analysis is weakest. As the report states, although improvements should have been suggested by standards and by budgeting, "the farm business method has no formal logical procedure for selecting between enterprises . . . in a way which can be claimed to result in maximum productivity or maximum profit for a known combination of land, labour and capital."

The "programme planning" method of analysis makes much less use of farm accounts. It aims to discover the pattern of the present farm business, the number of cattle, the acreage of different crops, etc. The object of programme planning is then to obtain the maximum returns from that factor of production which is limiting the expansion of the business. This it does with the aid of research data on such points as labour requirements, stock per acre, etc. For instance, in one district on farms of more than 160 acres, operated by a one-man farm family, it was established that labour was the limiting factor; whereas below 160 acres, land was the limiting factor. The proposed system is budgeted and tested against the efficiency levels established by research. The chief disadvantages of this method are its reliance on research data which is at present lacking in sufficient quantity or is still insufficiently tested, and its concern mainly with the choice of enterprises on a farm, whereas weaknesses in the management of many farms are not due to wrong enterprises but to inefficient methods of managing those enterprises. Therefore, although programme planning can be of assistance when considering the reorganization of a farm business, more detailed analyses of current practices are frequently needed before improvements in production

methods can be suggested. Nevertheless, the report can be recommended as a stimulus to current thinking about methods of farm management analysis in this country.

Grassland and Silage

V. H. Beynon has published a report [3] which seeks to underline the importance of grassland production in the British agricultural scene. The first part of the report consists of an analysis by counties of the area of grassland and the density of stocking. The difficulty of measuring the value of output from grassland is discussed, and a useful assessment of the relative merits of cow-grazing days, starch equivalent, gallons of milk and pounds of meat per acre is made. Mr. Beynon concludes that the starch equivalent is the least inaccurate measure available but that, with careful use, the cow-grazing day may provide a good guide for field-to-field comparisons of grassland productivity. Further sections of the report deal with existing levels of grassland production, and with two important factors influencing the level of output—reseeding practices and fertilizer usage. The data in the report illustrate the heavy dependence on permanent grass in the south-west, both for grazing and for haymaking. The author concludes that "there is strong evidence from some individual farm records that production from temporary grass is considerably higher than from permanent grass and that temporary leys are more likely to respond to heavy fertilizer dressings." The data on fertilizer usage show that high productivity of grassland can be achieved. However, this does not necessarily result in higher profits. Indeed, profits may be lower, unless the extra grass is utilized efficiently.

In a further report, Beynon and Langley [4] examine various aspects of self-feeding silage. A useful analysis of three typical bulk-food rations is made according to dry matter content, starch equivalent, and protein equivalent, and these are compared with theoretical feed requirements. From this study it appears that 75 lb of silage, combined with 56 lb kale, 112 lb of silage only, or 80 lb of silage plus 14 lb of hay, are all theoretically adequate for the maintenance of a dairy cow plus a production of from 1-2 gallons. Although the average performance of herds in the sample investigated falls below this level, on the basis of concentrate feeding, the explanations given for the discrepancy (high proportion of dry cows, low yields, etc.) seem reasonable. Certainly the concentrate feeding record of these farms was generally good since they were feeding 2.7 lb per gallon of milk in winter compared with 4 lb per gallon commonly fed.

The report concludes that "There seems to be every incentive to use silage and kale to replace dairy cake. Whether the self-feeding technique enables greater quantities of cake to be replaced than hand-feeding requires further investigation, but there can be no doubt that this technique can result in considerable savings in labour". On the labour side it is always difficult to put a monetary value on savings in effort or drudgery, or even on time saved, if there is no other job easily available. However, if it is possible to introduce or expand separate enterprises with a consequent increase in output, savings can be considerable. On

the farms in this survey the average labour saved was 1.65 man-hours per day during the self-feeding period. The idea of self-feeding for young dairy stock or store cattle could be immediately attractive to many farmers for whom the chore of feeding and bedding yarded stock in the winter is a constant burden. The survey results showed the consumption of silage by yearlings, who may eat up to 85 lb per day, and for two-year-olds, who eat up to 105 lb per day; these figures provide useful planning data. In conclusion, the survey discussed some of the pros and cons of self-feeding. It is a useful though by no means exhaustive addition to the volume of material which is building up on all aspects of the silage crop.

Another publication on the subject of silage feeding is of interest. D. P. Townsend [5] has carried out a detailed and carefully controlled study on the effect of feeding silage to dairy calves from an early age. A trial was carried out with a group of eight October/November calves in 1955-56, and eight September/October calves in 1956-57. Four calves in each group had silage introduced into their food when the youngest calf was four weeks old, and were fed exclusively on silage from weaning (at eight-and-a-half-weeks old) until they went out to grass. The other four were reared by conventional concentrate-feeding methods. It was found that the silage-fed calves were able to consume a greater quantity of silage than had previously been thought possible, the ration increasing from 6 lb when the calves were between one and two months old to 42 lb when they were turned out to grass at five months. Although little reliance is placed on the actual figures of liveweight gain at various stages, there is no doubt that the growth of the silage-fed calves was less rapid than that of the more conventionally raised bunch. Also, and more surprisingly, they suffered a more severe set-back than the other calves on first being turned out to grass.

The savings in cost can be quite substantial on a farm organized to feed silage for a long winter period. The figure of £4 10*s*. is quoted as the saving possible per calf raised on silage, even allowing for the increase in labour costs. However, the figures related only to the first year of the calves lives. The results may need to be re-examined when the animals calve down to determine whether rearing on silage has any effect on the performance of the animals after they enter the dairy herd.

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Regional Note

Commercial Practice in Rose-growing Nurseries in the East Midlands Region

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THE EAST MIDLANDS could aptly be called one of the main centres of the rose-growing industry, for in Nottinghamshire and Leicestershire, there is a large concentration of nurserymen who specialize in rose tree production. Many varieties of roses were already being grown for sale at the end of the eighteenth century. After World War 1 there was a great increase in small gardens, and with continued development through breeding, roses became more useful as garden plants, with the result that their production began to play a more important part in nursery cropping. Today, most of the larger rose-growers produce rose trees to the exclusion of all other nursery crops.

The development of rose nurseries in this area has been favoured by three factors: the suitability of the local soil (mainly Keuper Marl), the keen interest of local people in roses (Nottingham was the venue of the first rose show to be held in England in April, 1861), and the relative freedom from pests and diseases here in comparison with less industrialized districts.

The service provided by the rose specialist is the introduction, evaluation and propagation of roses, for, although a high proportion are introduced by growers in this area, few are bred locally. About five million rose trees are sold annually and include bushes, standards, climbers and miniature roses. Most of the miniature roses are grown in pots in glasshouses, and their cultivation is not described in this article. The importance of roses as cut flowers depends on the type of nursery. Most grow flowers for sale, but it is more important to the larger nurseries to supply the large quantities of blooms needed for show exhibits.

The following table shows the programme of cultural operations carried out during the development of the tree:

1957	Rootstocks (First Year)	1958	Maidens (Second Year)
Jan.	Rootstocks heeled in (grown from cuttings taken in 1955 or from seed sown in 1955-6	Jan.	Buds dormant
Feb.		Feb.	
*Mar.	Rootstocks planted and earthed up	Mar.	Rootstocks headed back to bud
*Apr.		Apr.	Buds develop to form maiden bush and produce first flowers
May		May	
*June	R. *rugosa* budded	June	
*July		July	Flowering continues Secondary growth improves size and grade of the bush
*Aug.	R. *laxa* and *canina* budded	Aug.	
*Sept.		Sept.	
Oct.	Buds dormant	*Oct.	Bushes lifted, graded, packed and dispatched. (This continues to a lesser extent until April, 1959)
Nov.		*Nov.	
Dec.		*Dec.	

*Periods of heavy demand for labour.

It will be seen that there are only short periods during which labour is likely to be available to carry out hand and machine cultivations. The planting of rootstocks in March and April may appear to be rather late but this is because no labour can be spared in November-December, and soil conditions are nearly always unsuitable for planting until late March.

Rootstocks

Knowledge of the use of rose rootstocks has been obtained by trial and error and there has been no investigation comparable to that on fruit rootstocks at East Malling Research Station. The principal rootstocks used are *Rosa rugosa*, *R. laxa* and *R. canina*. *R. rugosa* is the stock used for standards; *R. laxa* and *R. canina* are used for climbers and bushes. *R. rugosa* and *R. laxa* are consistent in performance, but *R. canina* in its common form is very variable, and because of this most growers use one of the many selections from *R. canina* rather than rely on seedlings from hedgerow plants.

PROPAGATION OF ROOTSTOCKS

Most of the rootstocks are imported from Holland and Germany but some are grown in nurseries from cuttings or from seed.

R. laxa from cuttings is a popular and useful stock. Cuttings 9 in.

long are taken in October from seedling stocks which were budded during the previous summer. All but the top three or four buds are removed, the cuttings are normally dipped in a hormone rooting compound and heeled in to await planting. Planting is done when the weather permits; autumn planting gives the best results.

R. rugosa shoots are taken from stool beds planted specially to provide stock. Cuttings are made 8 in. long, and after the lower buds are removed they are planted 9 in. apart in rows 3 ft wide. After the first year they are pruned hard to encourage strong shoot growth. One shoot is selected to grow on to form the stem of the standard tree. The resultant standard stocks are lifted, graded and planted in nursery rows where they are to be budded.

R. laxa and *R. canina* grow satisfactorily from seed, provided that the soil is well drained, free working and free from stones. The seed is collected when ripe, stratified in sand and/or peat, and sown from the following autumn onwards. As the seed chits early it is sometimes impossible to keep it in good condition if sowing is delayed until the spring. On light soils free from stones seed can be sown in drills without further preparation, but if the soil is heavy or stony the seed is broadcast on beds and covered with peat and sand. A good stock must have a clean stem (hypocotyl) between the root and the shoots.

Seed beds of rootstocks are difficult to weed, and it has been found that normal treatment with pre-emergence weed killers (P.C.P., tar acids and vaporizing oil) is effective in controlling weeds which germinate during the late autumn and winter.

The value of the seedling stocks is directly proportional to their size-grading, so it is important that there should be no check to growth and irrigation in dry weather together with spraying to control mildew are considered worth while.

STORAGE OF ROOTSTOCKS

Imported rootstocks arrive at the nurseries from November onwards. When received they are already graded for size and, with the exception of standard stocks, are in bundles of fifty. The bundles are normally heeled in intact, and in dry winters there is a tendency for the plants in the centre of the bundles to dry out before planting time.

Soil Preparations

MANURING

In the absence of any experimental data on the nutrition of roses as a nursery crop, practice is based on past experience. An adequate level of potash is considered to be essential; phosphates are often unnecessary in the older nurseries, and nitrogen dressings are adjusted to supplement the residues remaining from the previous crop.

The system of rotation affects the quantities of fertilizer and manure used. Where roses are grown frequently on the same land, heavy

dressings of farmyard manure and fertilizer are required to maintain adequate growth. In a wider rotation, including arable crops and leys, farmyard manure is less necessary and moderate rates of fertilizer are usually sufficient. It seems that, provided the soil structure is good, high fertility is not essential for rose production. If the fertility level is sufficient for good rootstock growth, there is no justification for applying additional fertilizer in the second (maiden) year.

It is generally thought that roses prefer a slightly acid soil (pH 6.3-6.5), but good plants are grown where the pH is above 7. Any soil with a pH below 6.3 should be limed. Ground magnesium limestone is generally recommended in this area, partly because of the favourable price and also because it is considered to be an insurance against possible magnesium deficiency where high levels of potash are maintained. Failures of rose crops due to soil acidity are not uncommon; *R. laxa* appears to be less tolerant of acid conditions than *R. canina*.

CULTIVATIONS

If roses follow a ley the turf is disced and well buried by the plough in late summer or autumn. Cocksfoot leys, when broken up, tend to leave large tufts which impede planting operations and because of this growers prefer a finer ley mixture such as ryegrass and clover. If farmyard manure is used it is put on before the autumn ploughing; lime, if needed, is spread after ploughing and fertilizer is applied just before working down the soil for planting.

Planting Rootstocks

Small areas of bush and climber stocks and all standards are still planted by hand. Some workers use a dibber while others work in pairs using a spade. Hand planting is slow and costly but it can be done when the soil is too wet for mechanical planting. A widely-adopted and partly mechanized method is to use an implement which makes a "grip" 7-8 in. deep. The rootstocks are placed in the grip by the worker who firms them with his heel. This method has some disadvantages in that the soil may fall into the grip before the plants are put in and the firming of the plants is sometimes insufficient.

Several types of planting machines are now in use. These, when properly adjusted for depth and spacing and handled by trained operators give results comparable with the best hand planting. Spacing is automatic and the plants are thoroughly firmed by press wheels, then earthed up in one operation. The speed of planting is not high, but is consistent as the pace is set by the tractor driver. The plants are spaced 7-8 in. apart with 30-36 in. between the rows. The wider rows, giving more space for inter-row cultivations are now preferred by most growers.

The rootstocks are planted so that the stems are above ground level, but after planting they are earthed up 3-4 in. so that the stems are covered with soil and this ridge is maintained until budding commences.

CULTIVATIONS FOLLOWING PLANTING

After planting, the rootstocks are kept free from weeds by tractor cultivation with mounted hoes. Rows of standards, having stems 4-5 ft high supported by wires and stakes can only be cultivated by smaller machines hoeing one row at a time. If the land is clean and the tractor hoeing accurate, little hand hoeing is needed before the following July.

Immediately before the rootstocks for bushes and climbers are budded the soil is "taken out" from the rows, i.e., the ridge of soil is drawn away with narrow hoes leaving the stems exposed for budding.

Propagation

Propagation by budding goes on from May to September. Budding commences when the bark of the stock lifts or "runs" easily. The season at which the stock "runs" varies with the type of stock and with its size.

The sequence in which stocks are budded is usually *R. rugosa* (standard trees), *R. laxa* cuttings and *R. laxa* seedlings, followed by *R. canina* seedlings. The period over which budding may be done is often extended by planting more than one size of *R. laxa* or *R. canina;* the smaller stocks being suitable for late budding. Buds for use in May and June are taken from glasshouse-grown roses, by July buds from maiden trees are ready, and these are used for the rest of the season.

Bush roses are budded with one bud just above ground level. Standards are budded at about 4 ft 6 in., three buds being inserted round the stem. Budsticks, from which the buds are taken, are selected by experienced and reliable workers. The stage of maturity at which the stems provide good buds varies; normally this is just after the flower has fallen but polyantha types may be ready while in full flower. There is also considerable variation in maturity from year to year and in the course of the budding season according to weather conditions. The budsticks are prepared by removing the thorns and trimming the foliage to leave a short piece of petiole. They are then placed in large tins containing an inch or so of water and kept covered with moist sacking until used.

Budding is done by skilled workers who put in 800 - 1,100 buds per day. They perform only one operation—cutting and inserting the buds —which are normally prepared by cutting them moderately thick and removing the wood from the shield. "Tying-in" of buds is usually done by young workers who still have supple backs, for this operation necessitates working for long periods in a bent position. Raffia cut in lengths of 18 in. is still used for tying, but other more reliable and standardized tying materials are replacing it. Rubber strips are widely used, and there is much interest in rubber strips or patches which can be wrapped round the bud very quickly and fastened with staples.

Post-Budding Operations

After budding, the stocks are sometimes earthed-up to prevent damage from bud boring beetles and to lessen drying out. Growth continues at a reduced rate. Little cultivation is possible at this stage for there is much other work to be done.

During the autumn, the moist warm conditions favour the growth of weeds, which can become troublesome. Hoeing at this time of the year is often ineffective and the weeds—generally chickweed and annual meadow grass—persist until the following spring.

In early February the top of the rootstock is carefully cut off just above the bud with long-handled secateurs. Cleaning or "chipping out" of the crop is the next job. The weed growth is often so dense that hoes cannot be used to remove it without risk of damage to the plants. It is then necessary to use narrow spades to chop out the weeds between the plants. Care must be taken because the bud which is starting to grow is very easily damaged. Inter-row cultivations by machine follow "chipping out".

When the buds have "grown out" they are sometimes pinched at 7-9 in. to encourage the growth of basal shoots, thus improving the grade of the bushes. As the flowering season approaches, if flowers are required for sale or exhibition, some of the stems are disbudded to a single bud. The highest quality flowers are from the maiden crop which is kept as clean as possible up to flowering time in early July. Subsequently, labour is so fully employed on budding the next crop, that little time can be spared for hand hoeing, and the rose fields remain colourful, but often rather weedy.

Lifting and Packing

On larger nurseries lifting machines are used which cut around and under the trees so that they can be easily pulled out. Lifting starts in late October when the leaves begin to fall; the loosening of the plants accelerates defoliation. They can then be removed in a reasonably dormant condition. Hand lifting is still done on smaller nurseries, the trees being lifted as required. This is a particularly laborious task which must often be done in bad weather.

After lifting the trees are graded and bundled. Those to be dispatched immediately are put into bins in the packing shed. Those required for later use are heeled in out-of-doors in sand bins.

Most of the trees are sent out in November and December, and during this period almost all nursery staff are fully employed in packing. Simple presses are used to compress the bundles of plants so that they can be tied, then the unwanted tops are removed by a guillotine. Large bundles are still packed in the traditional way with straw and hessian, but smaller bundles are put into polythene and waterproof paper sacks.

Pests and Diseases

In the East Midlands roses under field conditions are not seriously affected by pests or diseases. Aphids are not a serious pest and seldom justify protective spraying. Mildew is of little importance on maiden trees, but rootstocks can be affected by it. If mildew develops before the stocks are budded spraying may be necessary. Black spot is seen occasionally whilst virus symptoms are apparent in some varieties. Knowledge of rose viruses and their effects is limited and therefore little can be done at present to clean up existing varieties.

Raising New Varieties

Although some notable new roses have been raised in the East Midlands by a number of well-known breeders, most of the new varieties introduced here have been raised abroad. The lack of interest in rose breeding is due, not so much to our unfavourable climate, as to the lack of adequate financial reward for the raiser. Most new varieties are introduced from countries where the growers have the advantage of a plant patenting system.

Developments—Actual and Probable

We have seen many changes in growing techniques since the end of the war, particularly in the last ten years. Mechanization has saved labour and speeded up planting, cultivating, lifting and packing. Roses are being included in an arable rotation to an increasing extent, with the advantages of lower manure and fertilizer requirements and less competition from weeds. The advent of residual herbicides raised hopes that weed control in roses would be simplified, but although they show considerable promise, some undesirable effects followed their use last season.

Much interest has been shown in systematic lifting, grading and storage of trees, and in methods of assembling and dispatching orders: the organization of these operations could well be the subject of a work study. It is anticipated that within a few years it will be common practice for all trees to be lifted at one time, and placed in stores with controlled temperature and humidity.

The rose-growing industry has been stimulated by the introduction of new varieties, forms and colours. Growers have countered rising costs by better use of labour and machinery. As long as improvements continue, we can expect to see the rose-growing industry retain its important position.

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